Voltage Control and Stabilization of Electrical Voltage in High Voltage Power Grid by Controlled Inductance-Capacitance Parameters Equipment

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Abstract – This paper is focused on problem of voltage control and stabilization in high voltage grid. A way to decrease voltage deviation by using Controlled Inductance-Capacitance Parameters Equipment (CICPE) is proposed. Work experience of reactive power control scheme was confirmed at the oil field. Key results of implementation of Source of Reactive Power (SRP) based on Magnetically Controlled Shunt Reactor (MCSR) and Bank Capacitor (BC) in the power grid are shown.

I. INTRODUCTION

Considerable amounts of substations with high-voltage electric grid have fluctuations of voltage level under normal conditions up to 15% from nominal values. Over 40% of all substation in 110÷220 kV grids hold exceeding of voltage variations. Moreover, it leads breaking common standard and that describes limiting value of voltage variation as ±5% \[1,2\].

Similar instability of voltage in grid leads not only to limitations of conduct carrying capability, increased energy losses, and accelerated wear of equipment. It is a direct and obvious threat leading to complete power failure and system blackouts caused by multiple breakdowns \[3\].

II. METHOD

The key issue is that current methods of voltage regulation allow and even foresee the fluctuations of voltage happening with changes in operation conditions \[4\]. As a result, under maximum load, the voltage in the load node will fall, and under minimal load, the voltage will raise up to the highest permissible numbers. (Fig. 1).

One of the possible solutions to this situation is using Controlled Inductance-Capacitance Parameters to enhance voltage quality in the grid \[5,4\] (Fig.2).

Fig. 1. Main substation voltage \(U_1\) and load node voltage \(U_2\) under maximum load (a) and no-load running (b).

Fig. 2. Main substation voltage \(U_1\) and load node voltage \(U_2\) using Inductance-Capacitance Parameters Equipment.

This method allows finding such nominal and functional parameters of CICPE that complete voltage independence on load values from maximum to no-load.

III. PRACTICAL IMPLEMENTATION

Work experience of reactive power control scheme in electric grid 220/35/10/6 was confirmed on OOO NaryanmarNeftegas – oil and gas company.

Fig. 3. Reactive power compensation scheme in the electrical grid 220/110/35/6 OOO NaryanmarNeftegas.

Here is a report written by Chief Electrical Engineer S.L. Naiman November 1, 2010.

By the end of 2008, a difficult situation developed in a local electrical grid 220/35/10/6 OOO NaryanmarNeftegas during the process of turning on the aerial line 220kV, 150km long. As a result, the voltage increased considerably at the incoming end, and the reactive power flow increased up to 40
MVAR at the transmission end. Two gas-turbine units (GTU), 25 MW each, could not solve the problem and at least three of them were planned to be used. However, after using five of GTUs, the problem still remained. The continuous changes in the load had led to repeated failures and halts in the grid power. During 2009 and first half of 2010, more than several dozen of similar blackouts happened.

The situation changed drastically for the better when OOO ESKO developed and installed four Shunt Reactors (3.3 MVAR), one MCSR (25 MVAR) and two SRP (±25 MVAR each).

See result of installing MCSR by OOO ESKO during the second half of 2010 below:

1. The power grid 220/35/10/6 OOO NaryanmarNeftegas has been functioning steadily under wide fluctuations of load, up to 10MW.
2. The voltage has been regulated automatically in the range 220-230kV up to ±1kV independently from current loads (Fig.4, Fig.5).
3. Generators work without under-excitation under normal, starting or maintenance conditions.
4. The capacity of the grid 220/35 has been in accordance with nominal power values: 220kV – up to 100 MW, 35kV – up to 95 MW.

![Fig. 4. Voltage fluctuations on main substation.](image)

It has proven in a practice that the CICPE allows solving the problem of voltage regulation in any present-day electrical grid of 6 kV to 500 kV and remove the causes of systemic blackouts and crashes due to dangerous voltage raises and falls [6].

![Fig. 5. Voltage fluctuations on load node.](image)

### IV. KEY RESULTS

The installation of the CICPE in electrical grid will allow an automatic stabilization of the voltage up to 1-2% of the voltage setting value when using operational conditions as well as maintenance or post-accident conditions. Thus, electrical grid simultaneously realizes power transmission and active control of regimes. This equipment provides:

- automatic voltage stabilization in the grid of 6 kV to 500 kV in normal, maintenance, and post-accident conditions, within 5% from nominal values;
- exclusion of a switching equipment from voltage regulation in normal operational conditions;
- increase of current grid transfer capability up to 1.5 times;
- decrease in losses up to 20-30%;
- avoidance of under-excitation of generators;
- decrease in expenses to the consumers due to failure preventive automatic mechanisms [4].

OOO ESKO developed and built a special equipment for automatic systems of voltage stabilization:

1. MCSR 6,10, 35kV with power of 3,6,10,16,25 MVAR for insulated neutral electrical grid (MCSR 6÷35)
2. MCSR 110, 220, 330, 500kV with power of 25, 63, 100, 180 MVAR for grounded neutral electrical grid (MCSR 100÷500)
3. SRP 6÷500kV based on MCSR and BC with range of power from ± 3,6 to ±180 MVAR (SRP 6÷500)

OOO ESKO provides analysis, development, engineering, and supplying solutions for automatic systems of voltage stabilization. OOO ESKO customers are OAO System Operator of the United Power System (OAO SO EES), OAO Federal Grid Company of the United Power System (OAO FSK EES) and its affiliates, KEGOC, Lietuvos Energija; OAO Tatarstan Grid Company, OOO NaryanmarNeftegas, OAO NK Rosneft, ZAO Vankorneft, RAO Energy System of East (OAO «DRCK»), «Gazpromneft», etc.

Lately the total amount of OOO ESKO projects has reached about 7GVAR (Table I) [7]. The area of MCSR and SRP application would significantly increase over the next few years by implementation of Smart Grids and FACT-technologies.

### TABLE I

<table>
<thead>
<tr>
<th>№</th>
<th>Country</th>
<th>Quantity</th>
<th>Installed power, GVAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Russian Federation</td>
<td>84</td>
<td>6,2</td>
</tr>
<tr>
<td>2.</td>
<td>Kazakhstan</td>
<td>14</td>
<td>0,78</td>
</tr>
<tr>
<td>3.</td>
<td>Belorussia</td>
<td>2</td>
<td>0,36</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100</td>
<td>7,34</td>
</tr>
</tbody>
</table>
Thus, the implementation of the CICPE has just started in Eurasian Economic Community. The voltage stabilization in electrical grid becomes more important nowadays. The reason is high wear of electrical grid equipment, which can be valued as 50% [8]. Only economic methods are not enough to improve situation and achieve system benefits. There is a need in technical documentation that guarantee voltage control and stabilization by the CICPE implementation.

REFERENCES